FROM SPACE – OUR HOUSING HOPES?

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Introduction

It is obvious that if we are to build the new cities and new towns in cities (Fig. 1) urban planners are discussing, some pretty advanced construction techniques and materials are required. The real question, however, is: What will it take to build these towns and cities? This is not an easy question to answer, but let us attempt to examine certain aspects of the associated problems.

Although at this hour, unsympathetic voices to continued space efforts resound loudly over the land, it is easily shown that space developments have provided us with the know-how, the technology, and the approaches for dealing with many of our earth-based problems. This presentation deals with only one of these problems — Housing.

In these very brief moments, we shall give an overview of three points:

1. Material Advances

2. New Building Methods

3. Systematic Design and Building Management.

These three items will be treated from the viewpoint of the Design-Structures-Materials Complex, indicated by Figure 2 [1].

Material Advances

First, a brief word about materials. It is clear that there are many aspects to the proper selection and effective utilization of materials for a successful structural design, particularly one for severe environmental conditions. As Figure 2 illustrates, there are strong interactions among materials, structures, and design. Furthermore, because of these strong interactions, it is most important that the rational design of the system be approached on an integrated basis, considering simultaneously the structure, materials, and design conditions.

However, the ability to accept the world's available materials requires an inventive approach to the challenging demands of design. Dreaming about removing limitations of materials, however, provides powerful incentives for research. Ultimately, we may envision a heterogeneous solid (a mixed material system, perhaps) possessing the desired variable mechanical and physical properties which will simultaneously satisfy all of the design functions. Giving vent to our imagination, we contrive the ultimate structure (Fig. 3), a structure resulting from an interplay of the highest order.

New exotic materials emanating from space technology, such as titanium, beryllium, carbon, boron, and special glasses, offer many design possibilities. On a higher order, we have several new material mixtures, called composites, which are strong yet lightweight and able to withstand severe load, temperature, and corrosive conditions. These too are developments necessitated to meet requirements of high-speed aircraft and space vehicles. Composites, in fact, are seen now to approach dream materials with tailor-made properties.

In general, composite materials [2] are divided into five basic groups (Fig. 4) by form of the structural constituents which determine the internal character of the composites. Since the structural constituent is generally embedded in a continuous matrix of another material, the matrix is called the body constituent. The matrix generally encases the structural constituent, holds it in place, seals it from mechanical damage, protects it from environmental deterioriation, and gives the composite form. Concrete, for example, is one of our oldest and simplest composites.

In particular, recent trends in the structural use of plastics (more precisely, reinforced plastic composites) have demonstrated the great potentialities of structural plastics in building. In addition to lending themselves to an infinite variety of shapes (Fig. 5), structural plastics can be employed in strong, tough, lightweight, and even light-transmitting structures. Although certain of these developments can be expected to have practical solutions of building problems, a number of difficulties still remain.

New Building Methods

The urgent need to provide low-cost mass housing for the nation has posed a real challenge for the building industry. In particular, this need includes a variety of housing types; e.g., single-family detached units, low-rise, high-rise multiple units, etc. Let us examine a few of the proposed systems which show promise in meeting some of these needs.

Single-Detailed Units, Double Units. The following are some interesting designs for singular dwellings. These illustrative designs, selected for their uniqueness, are only representative of a variety suggested for the single-system housing market. During the past 3 years, a number of experimental designs have found their way into the literature.

Flexible-corridor dwelling. The Sam Davis system [3] is constructed of fiberglass and polyurethane sandwich panels, molded in C-shaped elements. The element is used as part of the floor, wall, and ceiling; four or more are bolted together to form an enclosure or room. In production, two molds are used: one for the outside skin and one for the inside skin. The space between the two skins is filled with a low density polyurethane foam. For other shapes, the "C" is cut at the factory to make either interior or exterior corners. Doors and windows are cut into the rooms on the site (Fig. 6).

Each room is connected to the others by flexible corridors, permitting many design variations, as suggested by Figure 7. Horizontally, electric services run through the units' subfloors and the corridors, the latter carrying also all mechanical systems.

Floating house. An amphibious structure [3], designed by Domenico Mortellito, is formed in two molds — one for the top, the other for the bottom — the two sections are bolted together (Fig. 8). Constructed of rigid urethane, such a structure could be molded, extruded, and cast by processes incorporating structural, insulation, acoustical and lighting factors. Rigid urethane is a flotation material impervious to the elements and thereby particularly suitable for such a structure; the design is by no means limited to the amphibious application. Figure 9 shows the bottom half of the house (at the top).

MASC extrusion process. A revolutionary new construction technique for continuously extruding buildings was developed by Midwest Applied Science Corporation (MASC) of West Lafayette, Indiana. The new MASC extrusion process makes it possible to "spin" buildings out in one piece (walls, roof, partitions, etc.) (Figs. 10, 11), and not piece it together from components, on the site. Fast-rising and hardening plastic foams are used as construction materials. Fast-reacting liquid ingredients are pumped through the arm into a mixer and immediately transferred into a molding form at the end. As the arm moves along, a continuous layer of material is deposited.

Foaming equipment and supply tanks are mounted on a truck, and the system in its entirety can be moved to the construction site without need for auxiliary equipment. The process is applicable to structures of all types and sizes, including farm shelter, warehouses, factories, and low- and high-rise buildings. The traveling mold is designed so that construction is not restricted to any one geometry. Any shape of wall, whether straight or curbed, can be erected. Figure 12 shows how the process can be used to generate other shapes. An articulated arm could be used that could be shortened or lengthened, or whose center of rotation could be shifted. Still other shapes could be generated by moving a linear slip along a pair of inclined edge ribs.

Filament winding. In addition to the exploratory work on composite materials, aerospace research and development has contributed to a useful fabrication procedure for building. This is the wraparound technique, exemplified by the filament winding of rocket cases, pressure bottles, and other aerospace components.

By winding continuous strands of resin-coated glass filaments on a collapsible mandrel (Fig. 13), high-strength, lightweight structures are achieved whose strength properties are tailored to meet the imposed stresses by orienting the filaments in helical, longitudinal, or circumferential directions as needed. This technique has been tried experimentally to produce room-sized boxes with two thin layers or facings of filament-wound resin-coated glass fibers surrounding a core of lightweight plastic form.

An extension to wraparound consisting of a combination of fibrous sheets, gypsum board, and honeycomb has been proposed for industrialized housing production [3].

Architectural Research Laboratory (University of Michigan) system. The Architectural Research Laboratory (University of Michigan) [5] has proposed a complete building system which utilizes the filament-wound technique (composite concept) to produce onsite housing shells (Figs. 14, 15). The inner and outer skins, only 0.10 in. thick, are separated by a nonburning polyurethane core 6 to 9 in. thick, to form tubes up to 36 ft long, 20 ft wide, and 8 ft high. Various combinations of these can be assembled, including two-story units whose inner skins are wound separately, and after core application, are combined for outer windings.

Lift-shape process. The lift-shape process [6] is primarily a method of construction of thin-shell structures that permits elimination of conventional form work. A structural skeleton is developed so that it can be fabricated on a horizontal plane and then lifted and warped (Fig. 16) into final position (Fig. 17) for a spray covering of concrete (Fig. 18) or other material.

The shapes that are available through various patterns of bars are almost infinite, and the creative imagination of the designer would seem to be the only limit on shapes available (Fig. 19). As the armature is warped from its horizontal position and assumes a finished shape, the naturalness of structural form becomes apparent; and, as the sprayed-on covering is applied and the structure is brought to completion, the sculptural qualities are readily apparent (Fig. 20).

Self-erecting structures. Significant among the new construction methods is the self-erecting structure. Present developments, significant as they are, are but transitional steps toward the fully automatic self-erection of structures. Ideally, a self-erecting structure would be brought onsite in some compact form. Then, with the addition of an energy input, it would automatically develop into a predetermined, expanded, stable form. Figure 21 [7] illustrates a variety of structural shapes and space applications and their deployment techniques. The space program has exploited these structures in a way which may be very applicable to architecture.

Self-erecting structures of the pneumatic type (Fig. 22) can produce a large variety of shapes by tailoring the fabric, providing internal elements and external restraints. The simplest form of pneumatic structure is that of the inflated membrane. The inflated rib is under pressure inside the rib and unlike the air-supported membrane, it does not require a heavy foundation to withstand the large uplift forces at the support. The quilt provides continuous multiple membranes. The pillow construction consists of two membranes held apart the desired distance by internal ties. Intersecting ribs provide a two-way enclosure with membranes between the ribs. Of course, most pneumatic structures are inherently self-erecting in that only air need be injected to develop a stable expanded shape from a compacted form [4].

Environmentalists will find William Moseley's imaginative design [8] most satisfying. The house, swimming pool, patio and gardens are enclosed in a plastic umbrella (Fig. 23). A boom extending over the house supports the umbrella and contains all plumbing and wiring. Sections of the bubble are mounted on tracks, and can be opened or closed at pushbutton command. Inside the umbrella, air is filtered; climate is controlled. Entry is provided by a driveway passing through an air curtain.

Finally, the potentialities of a newly developed structural system may be gaged, to some extent, by its versatility in being able to satisfy expected future trends on a broad basis.

Multiple Units, Large-Scale Units. Several of the techniques just discussed have direct application to the construction of multistory structures and large-scale housing units. Since we shall deal with the subject, in part, in our discussion of construction on a vast scale, for the present, only two from among several techniques applicable for multistory construction are examined.

Pneumatic construction. A recent development of the University of Sydney, Australia [9], has resulted in the application of pneumatic construction to multistory buildings. The underlying principles of the proposed system are illustrated in Figures 24 and 25. According to Figure 24, a flexible tube, when subjected to a proportionate internal air pressure, becomes a stable compression member. Furthermore, it is possible to utilize the load-bearing capacity of this structural system, whether the load is applied externally to the free end or suspended internally in the form of floors.

A typical design of a 10-story office building based on pneumatic criteria is shown in Figure 21. In the design on the left, access to the building is gained by means of an airlock tunnel at ground floor level. At ground and basement level, substantial plant areas are required for air-conditioning and pressurization equipment. These areas are not pressurized. The variation on the right shows a rigid, self-supporting membrane which is erected to full height before the building is pressurized. Here an open, pressured column supports a load on a piston which is in itself supported by internal pressure.

Tentatively, a pressure range of 0 to 14 psi internal pressure above external atmospheric pressure has been adopted for the design of multistory pneumatic buildings [10].

Modular high-rise system. The system developed by National Homes for Operation Breakthrough [11] combines a precast concrete space frame with steel modular boxes. The structure is extruded round sections of concrete pipe with a post-tensioned X-frame every four floors. The precast central core of the cruciform-shaped building contains the stairs and elevators. A crane is used in this construction, which limits structures to 24 floors. After the precast elements are erected (Fig. 26), the boxes are lifted and slid in on top of each other. Four pairs of modular boxes can be stacked on each X-frame. A typical one-bedroom box is shown in the bottom right of Figure 26.

Several types of small modules are joined to form each 14 in. wide unit. It may be desired, for example, to have several bedrooms and a bath in one module, and a living room, kitchen/utility core, and bedroom in another. Furthermore, the modules can be placed side by side or can be stacked up.

New Communities, New Cities. In contemporary society, we no longer expect people to stay rooted for reasons of family loyalty, economic security, or emotional attachment. Families move. Jobs change. Populations shift. Each year one out of every five American householders moves, changing homes, as they change jobs, income levels, spouses, age groups, desires, and life styles. The constant tearing down, remodeling, and rebuilding that occurs in today's cities testify to the fact that continual change is needed and desired. New approaches which address themselves to these contemporary requirements of mobility and reversibility are the subject of the present discussion.

The concept of reversibility [12] is rather new to architectural design, and perhaps, a few preliminary remarks are in order. This is a form of architecture that can be dismantled nondestructively or collapsed in a reverse manner to that in which it was erected. As the life process of a city changes, the location of many structures would optimally change with it. A certain shop, for example, might be forced to abandon its location for particular reasons. If the building were designed for easy reversibility and shipment, it might not only be moved to another part of the city, but perhaps to another city or state.

Reversibility, however, is not intended to be restricted to small buildings, as is possible today. With technological developments, it should be possible to sectionally and systematically dismantle a structure of any size, including megastructures. An evolutionary trend toward hard, large-scale reversible structures can currently be noted, particularly in housing. The well-publicized Moshe Safdie's high-rise Habitat (Montreal, Canada), and the 21-story Palacio del Rio Hotel (San Antonio, Texas) are possible solutions to reversibility, although neither was originally intended to be reversed.

The Acron house (Fig. 27), designed by Carl Koch, in 1948, is an example of a prefabricated house that utilized initial deformability characteristics. Initially, the house is a movable package of approximately 180 square feet. The walls, floor, and roof fold around the central utility core — kitchen, heater, and bath. Closets are also stored here when the home is folded. When expanded the house contains 810 square feet.

More generally then, architectural form can be inherently deformable, expandable, displaceable, disposable, and to some extent, capable of kinetic movement [12]. To take full advantage of these characteristics, however, there must be established new criteria for materials, new technology, new construction techniques, new building economics, etc.

Reflecting some efforts in this direction, the following multifacility systems have been proposed for urban or regional populations:

Arcology. Paolo Soleri conceives future cities with more than a million people living in vast multilevel structures. Soleri's city-design concept, called Arcology, is an integration of architecture with ecology. It is a total planned environment, dwellings, factories, utilities, entertainment centers, within a single megastructure 1 to 2 miles wide and up to 300 stories high. Making maximum use of three-dimensional space, freeing nine-tenths of the surrounding land for farming and leisure, arcology combines the benefits of urban and rural life and provides alternatives to congestion, pollution and resource waste. Because the diameter of an arcology is small, walking, bicycling, escalator, elevator, moving sidewalk, and pneumatic or electric vehicle transport make automobiles unnecessary except for travel outside the arcology.

Two examples of such multilevel structures are: the three-dimensional Jersey and the Hexahedron (Fig. 28). The three-dimensional Jersey (top) is a 13-mi^2 transport center for a million people, planned for Jersey swamps. The main structure is circled by park-covered industrial buildings, farms, airstrip, etc. Two Hexahedrons (bottom) are each 3600 ft high, 3300 ft wide, and house 170 000 people. Pyramids textured surface permits architectural adaptation to individual tastes and needs.

Although the conceptions have been rejected by some as mere pipedreams, they do represent real challenges for the interplay between structure, material, design, and, of course, ecology.

Plug-in city. In architecture and urban planning, the concept of interchangeable components had been explored by two groups in particular, the Archigram Group (England) and the Metabolists (Japan). The objective is to create buildings which are so basic and adjustable that they can meet future changes. In the most general terms, the results are designs which are of indeterminate form, assembled from expendable components. Basically, the buildings are composed of two components: a basic skeleton or latticework or mast which acts as structural supports and carries mechanical services, and expendable modules or capsules which can be plugged-in, removed, or replaced.

The plug-in city (Fig. 29) [14], by the Archigram Group, is a complete urban complex that explores many aspects of the concept. Cranes remove, install, or service substitutive accommodation capsules. The giant latticework serves for both life support and structural support. Lateral expansion can take place along the lines between A and B. Plug-in city has been described as "a city of components on racks, components in stacks, components plugged into networks and grids, and a city of components being swung into place by cranes." Its success, however, may depend upon new lightweight, fireproof, and economical structural materials; equally important are new, quick, and cheap techniques of fabrication.

Super-roof structure. An instant plastic building has been developed by the Ferro Corporation. The process employs flexible plastic material that hardens under sunlight in hours or in days, depending on the sizes of the structure and the temperature. Once cured, the material is claimed to be relatively indestructible. The material may be possible to build structures up to 0.5 mile in diameter. The ultimate size will be established after complete stress analysis of full-size structures. Made of woven fiberglass impregnated with tough cylindrical plastics, the structures are translucent, permitting 80 to 90 percent light transmission. They are dome shaped or cylindrical in outline. The light weight of the finished shell makes these structures easy to transport. A structure 50 ft in diameter should weigh about 2500 lb.

In the future, immense super-roofs utilizing this concept could cover entire cities. Such megastructures are depicted in Figure 30 [15].

Sea city. The technology to build floating cities already exists. One proposal for such a floating city is the recent Triton City [15] designed by Buckminster Fuller. The city would be created in three stages. The first stage, or module, is a neighborhood of from 3500 to 6500 people. It can be composed of a string of four to six small platforms accommodating about 1000 people each or of a larger 4 acre triangular platform which could house 6500 people. Each neighborhood unit would contain a small supermarket, an elementary school, and local stores and services. The second module (second stage), a town, is created by linking together three to six neighborhoods, which would create a population of 15 000 to 30 000 people. For this combination, a town platform is added containing a high school; more commercial, recreational and civic facilities; and perhaps, some light industry. The third module, the last stage, is a full-scale city of 90 000 to 125 000 population. It is created by connecting three to seven towns and will include a city-center module containing governmental offices, medical facilities, etc. Units, of course, could be added or subtracted if the needs of the community should change, thus allowing and providing for incremental growth. The proposal is being considered for implementation by Baltimore, Maryland.

The city at sea (Fig. 31) [17], conceived by Pilkinton Glass Age Development Committee (London, England), is another proposal of the concept of floating cities. The designers envisage a glass-and-concrete offshore island for 30 000 inhabitants that could be comparable in cost to a conventional land city but would not use vital food-producing land. The site suggested for the first sea city is 15 miles off the east coast of England in shoals covered by 35 ft of water at high tide. Although such a project may not be realized for 50 years, the structural and engineering techniques needed exist today. Sea city could also be economically feasible and capable of providing all the facilities of a mainland town. The complex would be a 16-story amphitheater on piles, with a central lagoon warmed by waste heat from the city's industries and containing a cluster of floating islands that carry houses, schools, and public buildings. A breakwater of water-filled plastic bags would encircle the city as a first line of defense against waves, and a curved outer wall would deflect the wind. On-the-spot power from undersea natural gas would be the keystone of the city's economy and surplus fresh water from a desalination plant could be piped ashore to provide revenue. According to the designers, the kind of shoal water best suited for the construction actually exists over nearly 10 percent of the world's seabed, so there is no lack of suitable sites.

Undersea community. There is an ever-increasing possibility that undersea working and living may become a reality. Following Jacques-Yves Cousteau's underwater explorations and demonstrations of undersea living, several designs for undersea habitats are the subject of experimentation of several countries: U.S., Japan, United Kingdom, USSR, West Germany, etc.

One interesting design is a sea igloo, proposed by Edwin A. Link. Made of heavy-duty rubber, the igloo is actually an inflated house which works on the principle of maintaining equalized inside and outside pressures. When not in use, the igloo can be deflated, packaged and easily removed. An artist's concept of an underwater environment is shown in Figure 32 [18]. It is a "shirtsleeve environment" working and living facility, designed for depths up to, perhaps, 600 ft. A recent development of General Electric, an artificial gill, may free man from today's umbilical ties between undersea shelters and the surface and, eventually, from today's typical oxygen breathing apparatus used by divers. It is an ultrathin membrane of silicone rubber which admits air from the surrounding water and allows carbon dioxide from breathing to escape.

Space city. The ability to initiate efforts for actual living in space is largely based on the capabilities and experience obtained from over a decade of space exploration. The U.S. Skylab and Space Station programs and those of the USSR are clearing the way for mass utilization of space for habitation. Designs for space cities have already received serious consideration. Douglas Aircraft, for instance, has proposed a space ball complex which has a molecular structure that could be added to, much like a giant Tinker toy. Other proposals include enormous wheels and multispoked configurations in which the inhabitants circulate to other chambers via hollow spokes. The design (Fig. 33) is a space city complex with an average population of about 4000. The giant wheel consists of modules containing offices, laboratories, living quarters, and a hotel. A ferry system, perhaps similar to the proposed Space Shuttle of our own space program, would transport people and supplies from earth.

Systematic Design and Building Management

Among the approaches to provide low-cost mass housing, it appears that the creation of an industrialized system of building, one that is fully automated, technologically advanced, well managed, and most important, free from artificial impediments, may be the best hope in the attack. In other words, it is felt that it would be achieved through an integrated approach. This suggests a systems approach to the problem.

The systems concept is a way of thinking and approaching problems, which involves looking at the entire problem rather than concentrating on one or more parts to the exclusion of everything else.

Systematic management, aerospace's most characteristic product, offers the broad-based, interdisciplinary approach so necessary to solve the extremely complex housing problem. The problem is not one of a purely technological nature but one requiring the proper adaptation of technology to the human interface in the city.

In closing, we will examine the general features of the systems approach as it may be applied to housing. First, however, a few definitions are in order to avoid the confusion resulting from the often indiscriminate use of the technical terms.

Systems building is a combination of parts in a whole. In systems building, the term building system is used for an entity comprised of subsystems that are fully coordinated and interrelated. Industrialized building is programmed and systemized building using a highly mechanized flow line. Prefabrication in building is the offsite fabrication of components or assemblies. Prefabrication is not prerequisite to industrialized building, even though it usually plays an important role in it. Figure 34 [19] illustrates the various elements of the building system.

Conceptual Model of the Housing System. There are five major elements in the conceptual model [20] of the housing system. First, there are people. The people exhibit many different characteristics, one of the most important of which, in terms of housing, is that to the owner or renter of a house. Second, there is the roof-finding system, which includes all institutions and individuals engaged in the process of finding and securing homes for people to live in. The third element is the collection of houses and residential land in the area. The fourth, and most important, is the match between the house and the renter and landlord or owner, called the house-occupant (H-O) pair. The fifth is the neighborhood or community, and a sixth is interest rates.

The model diagrammed in Figure 35 includes seven system elements. Two major processes are represented: the process involving people, or migration, and the process involving the housing inventory, or deterioration. In addition, two types of action are defined: those involving physical processes (double arrows) and those involving perceptual processes (single arrows). The forces acting on people are produced by physical processes, whereas the forces acting on the houses are the result of perceptual processes.

The change in people and the people themselves are represented in blocks 2 and 3, respectively. It is postulated that the H-O pairing (block 1), the neighborhood and community characteristics (block 1A and Table 1), and the external influences (block 4 and Table 2) are forces which, modified by the internal characteristics, act on the occupant to produce his behavior.

Consider now the blocks and loops. First, the double-arrow physical-process loop starting with block 2, which represents the occupant. There are two arrows out of this block, representing the decision outcome to stay or move. If the person stays, he then remains in the neighborhood matched to his house, as represented by the double arrows from box 2 to box 3 to box 1. His living in the house implies some physical effect on the house, both in terms of wear and tear and in terms of repairs or improvements. These physical processes are represented by the double arrow emanating from the house-occupant set (box 1) and entering the box representing change-in-house characteristics (box 5).

The second double arrow out of box 2 indicates the occupant's decision to move out of his house and neighborhood. In the event the person moves out of the neighborhood, the house to which he was matched leaves the neighborhood housing inventory (box 6) and becomes part of the roof-finding system inventory (box 7). Once matched, the new house-occupant pair reenters the neighborhood (goes from box 7 to box 1) [1A].

The single-arrow pair from box 1 to box 5 represents each of the physical processes (wearing out, repairs, maintenance) in turn. The loop from box 1 through boxes 5 and 6 back to 1 represents the deterioration process.

The Construction System. Buildings and the processes that create and put them into place are manmade systems with humanly defined objectives. A building, for example (like any other designed facility, for that matter), is a system, that is, an interconnected complex of functionally related components designed to accomplish a purpose [21].

Since the system is made up of components, they, in turn, constitute wholes with their own ordering of parts. The system then consists of several subsystems related one to another, each possessing the basic systems framework. Figure 36 [21] illustrates the construction process (the Construction subsystem), a subsystem of the building system.

Let us consider the structural model of the Construction process. The Construction process comprises three main steps: site preparation, component fabrication, and component connection. The process is affected by the Design process in the form of design specifications (materials, components, dimensions, and arrangements which together make up a building or facility). The design specifications, together with other inputs, enter the Construction process. The inputs are: land, labor, materials, capital, know-how, and design specifications. The objective is to achieve a building or facility with specified characteristics and subject to certain constraints. The constraints of the Construction subsystem are technological, institutional, economic, and climatic.

Some of the restrictions come from outside of the subsystem, others from inside. Feedback control within the model works in two ways. Should the performance criteria indicate discrepancies between inputs and objectives, changes in construction inputs are provided, and perhaps changes in the inputs of the design process are required.

Conclusion

Obviously, in this brief overview, a number of aspects of our subject have, of necessity, been omitted. We did not, for example, discuss the various building systems themselves. Space limitations necessitated that such specific, but noteworthy information be sacrificed for a more general exposure.

In the foregoing, we have attempted to offer some developments of material systems and building methods that could be brought to bear on the complex housing problem. Some steps are already taking place. In addition, a suggested approach for dealing with the problem as it relates to other components within the total community or city structure has been mentioned. Most of these developments are traceable, directly or indirectly, to the space programs.

The degree to which these and other developments ultimately are utilized in the housing or building industry depends on the foresight, ingenuity, and progressiveness of the building industry itself. The potential for good design and for bringing good housing down into the price range where every American family can afford it and where we can make a serious start to rebuild our cities seems unlimited.

It is well, then, that we end on that optimistic note.

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TABLE 1. NEIGHBORHOOD MODEL CHARACTERISTICS [21]

Distribution of (mean and variance in)

1. People
   a. Race
   b. Age
   c. Income
   d. Occupation
   e. Education
2. Houses
   a. Age
   b. Assessed land value
   c. Assessed house value
   d. Number of people/[illegible]
   e. Number of people/[illegible]
   f. Number of people/bedroom
   g. Time since last sold
   h. Time on market
   i. Percent for sale
   j. Deterioration

TABLE 2. EXTERNAL INFLUENCES [21]

School quality
Crime rate
Public transportation
Redevelopment projects
Leisure facilities
Zoning
Employment opportunities
Surrounding neighborhoods – deterioration, racial composition, stability
Taxes
Finance

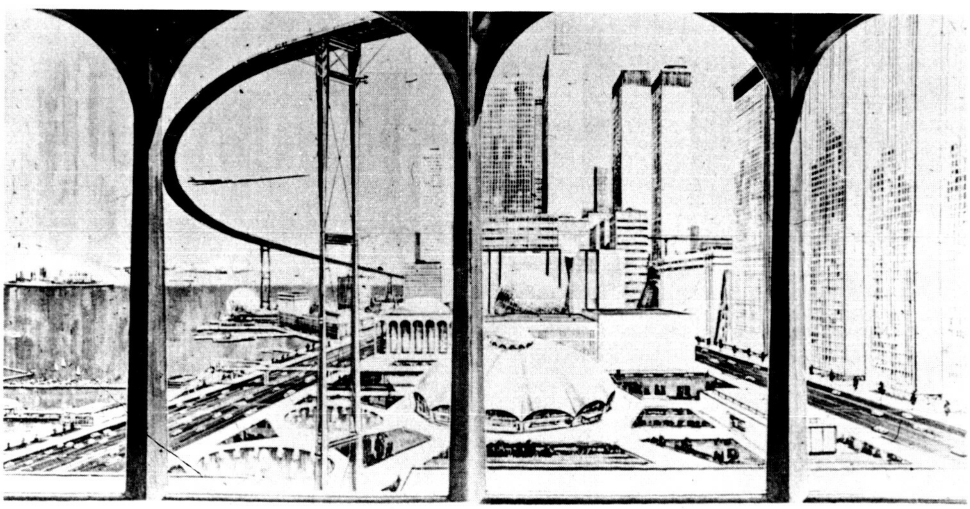


Figure 1. Our new city.

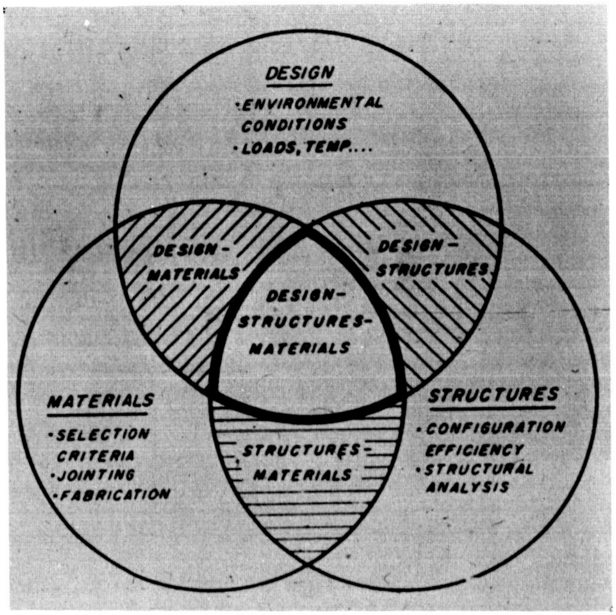


Figure 2. Nature of the interplay (courtesy of Aero/ Space Engineering).

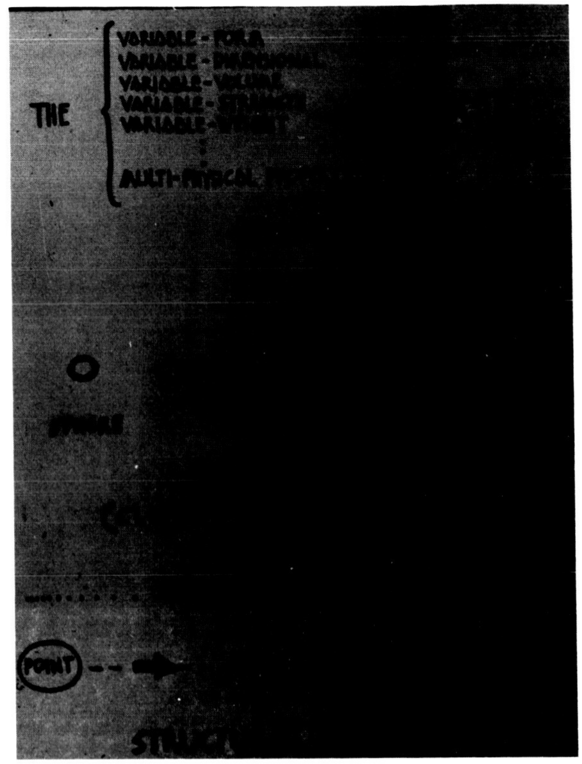


Figure 3. The ultimate structure.

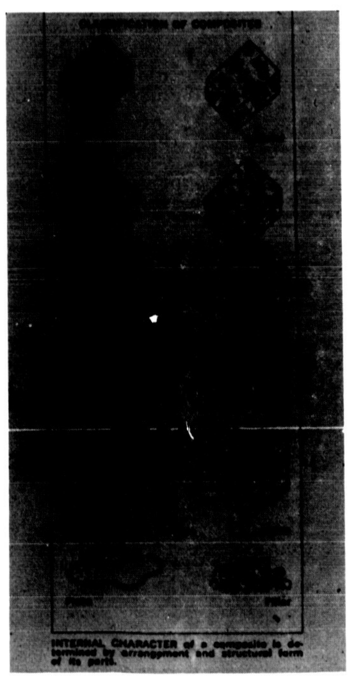


Figure 4. Composites.

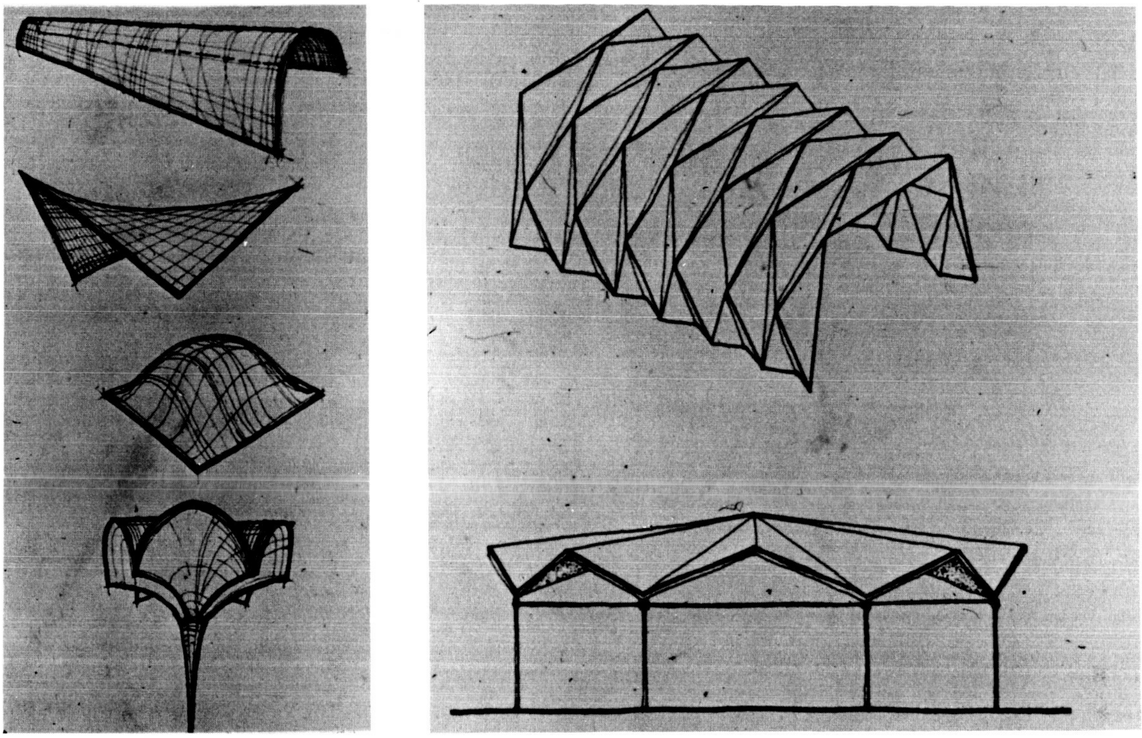


Figure 5. Some structural plastics shell forms (courtesy of Progressive Architecture).

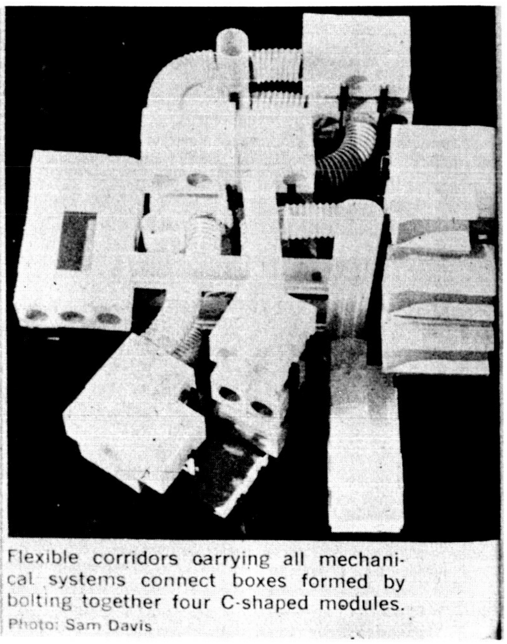


Figure 6. Flexible-corridor dwelling (courtesy of Progressive Architecture).

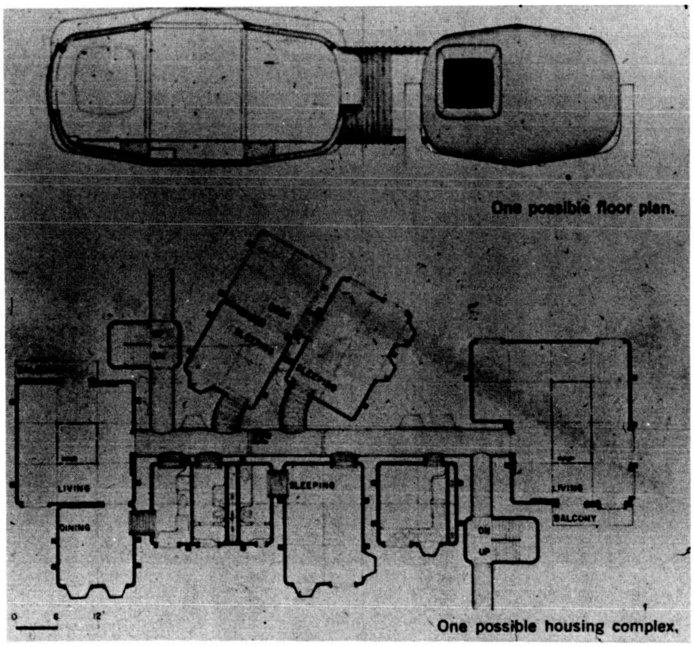


Figure 7. One possible floor plan for flexible-corridor dwelling.

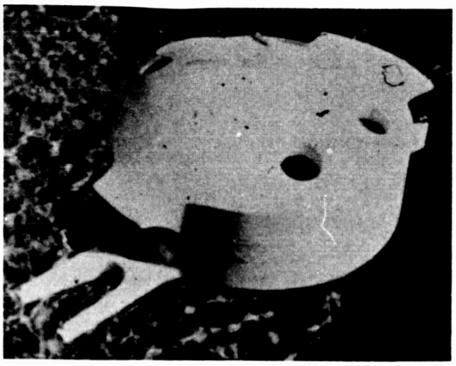


Figure 8. Floating house (courtesy of Progressive Architecture).

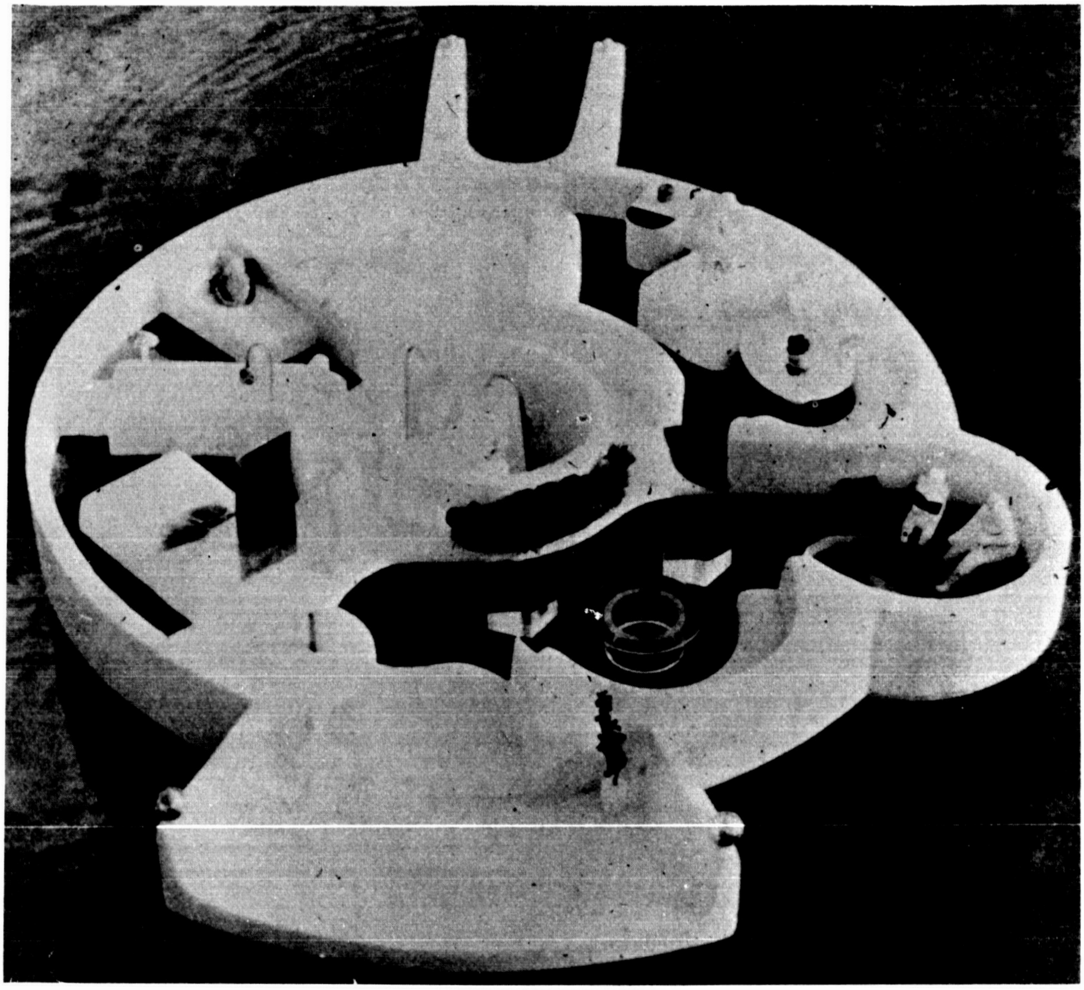


Figure 9. Bottom half of floating house.

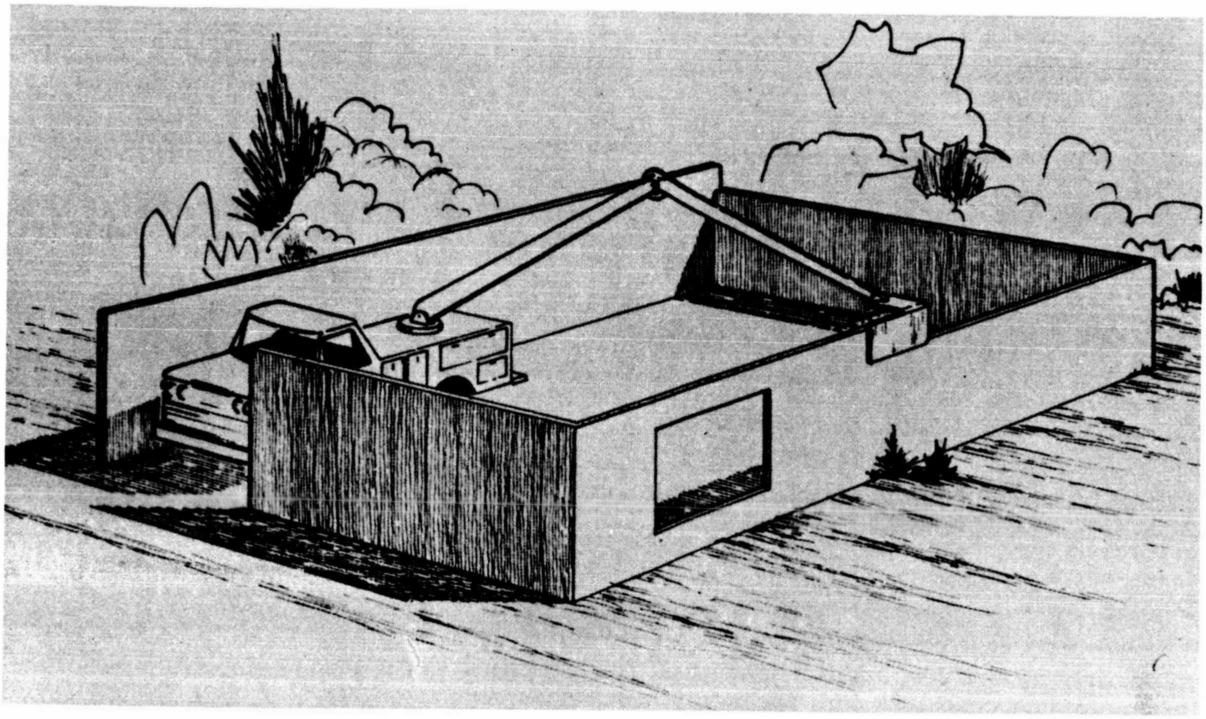


Figure 10. MASC extrusion process — wall formation of a rectangular building.

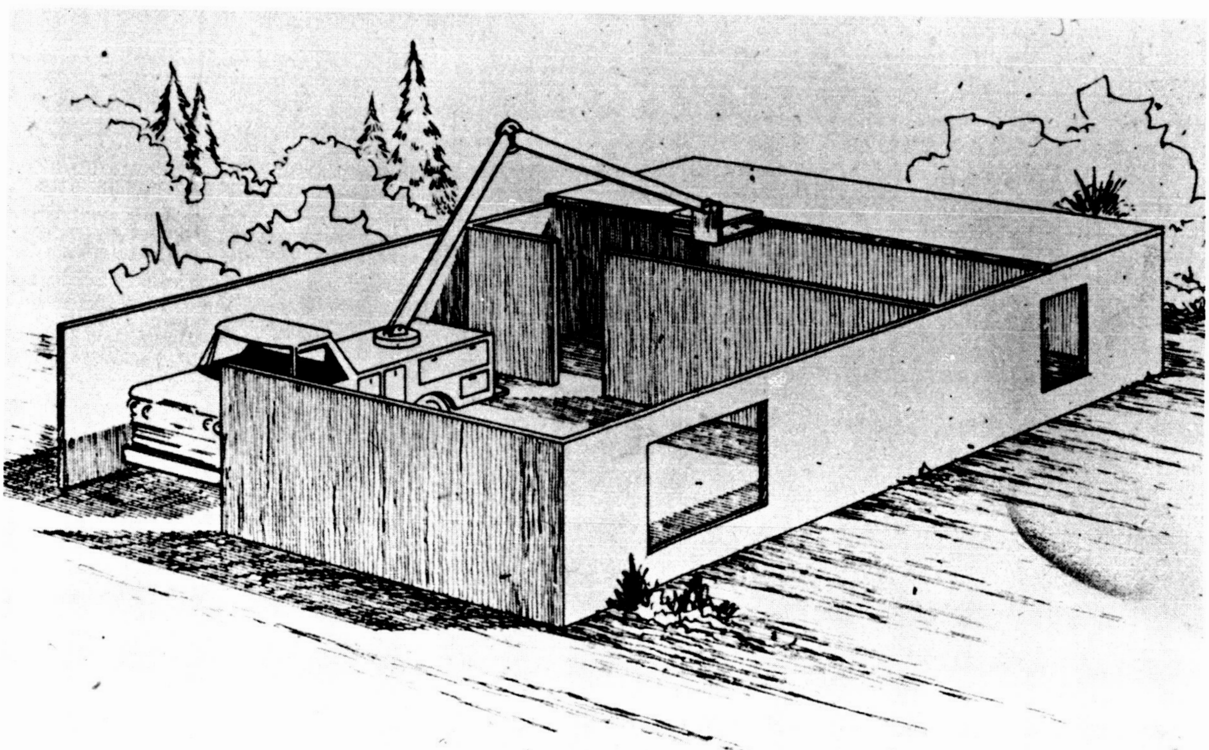


Figure 11. MASC extrusion process — ceiling and roof formation.

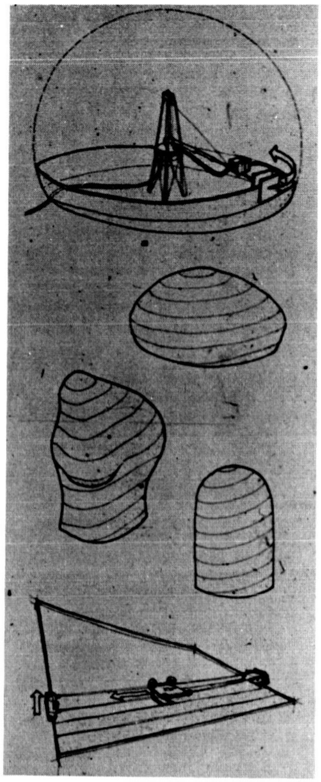


Figure 12. Some extrusion shell forms (courtesy of Progressive Architecture).

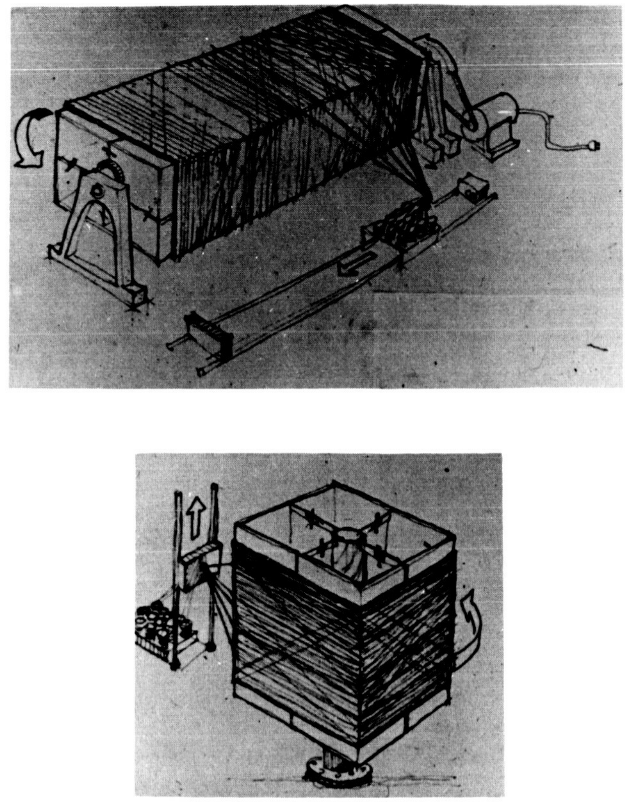


Figure 13. Filament winding (courtesy of Progressive Architecture).

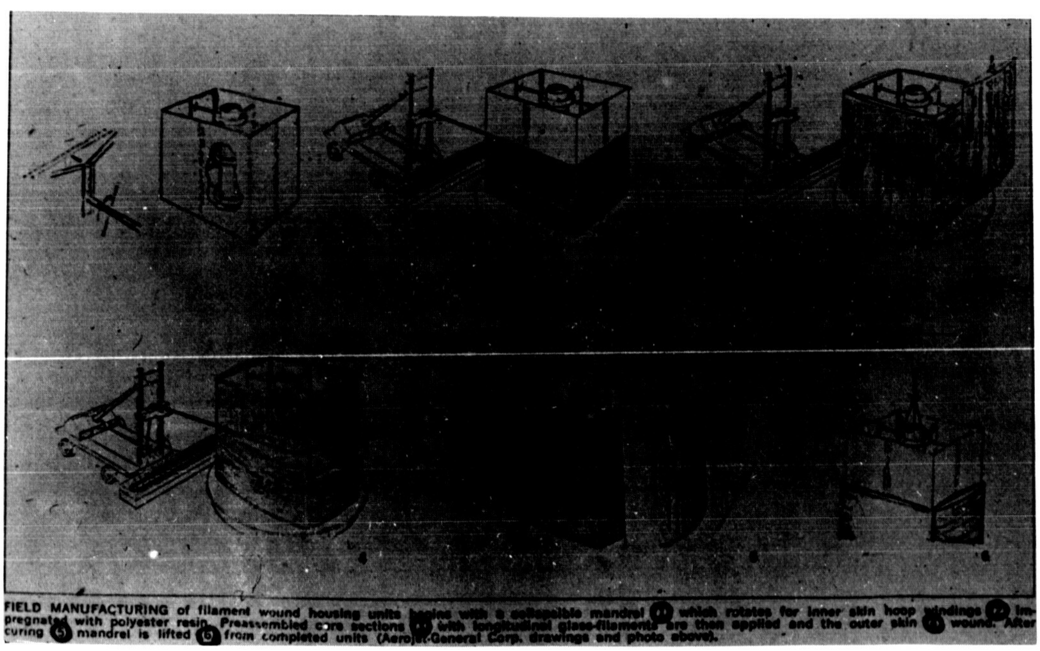


Figure 14. Architectural Research Laboratory (University of Michigan) system.

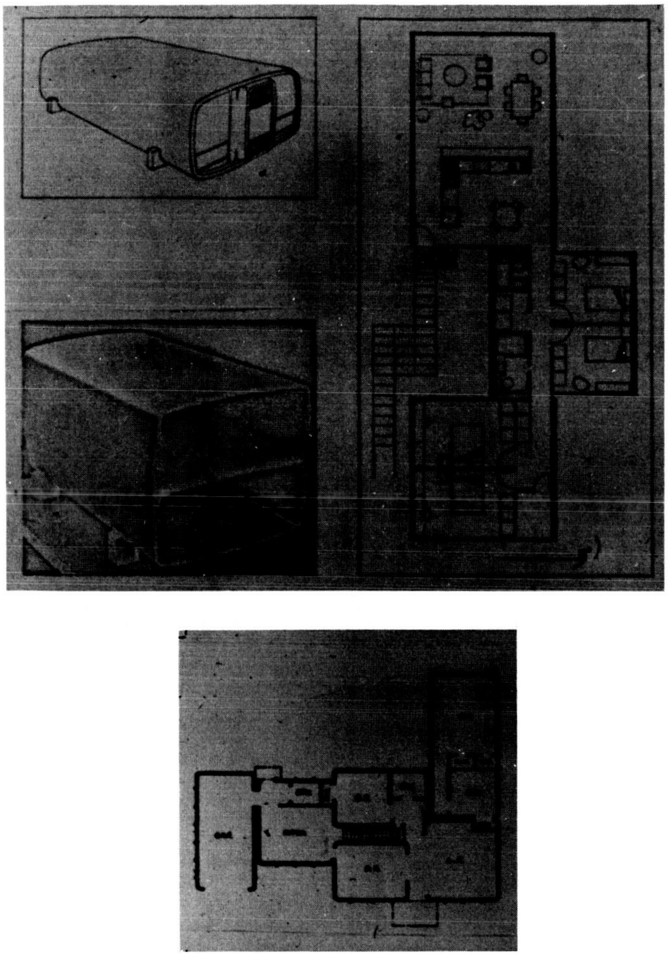


Figure 15. Completed units.

Figure 16. Lift-shape process [6] — placing temporary supports.

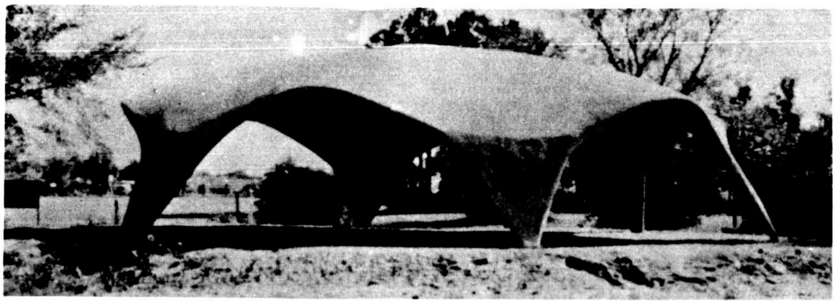


Figure 17. Final stage of construction [6] — completed steel armature.

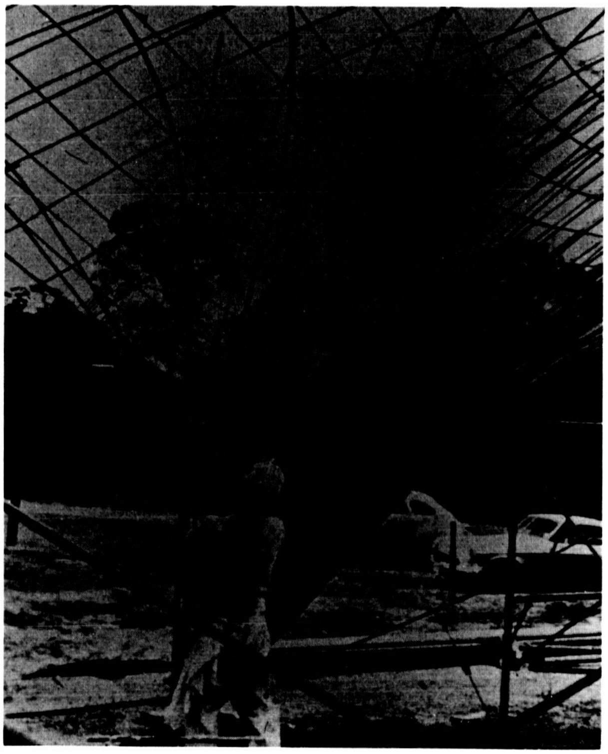


Figure 18. Final stage of construction [6] — spray application of first concrete coat.

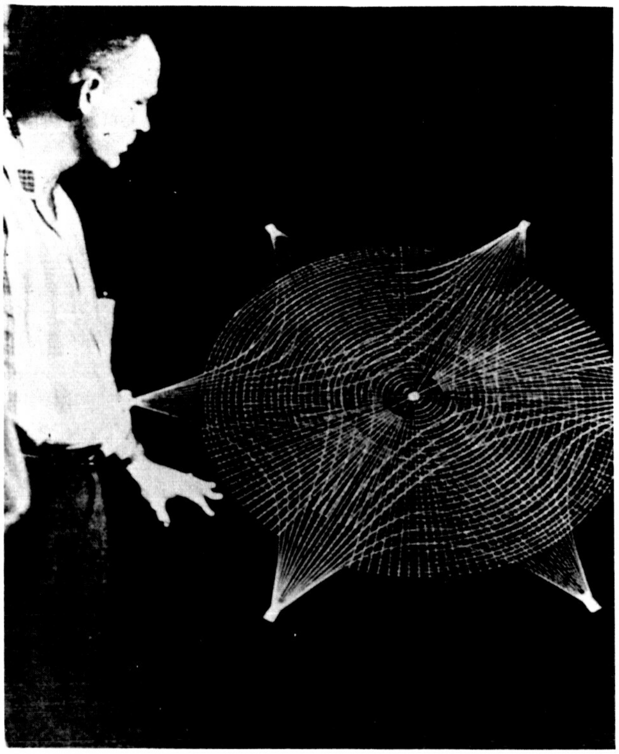


Figure 19. Bar pattern model of 50-ft span test structure.

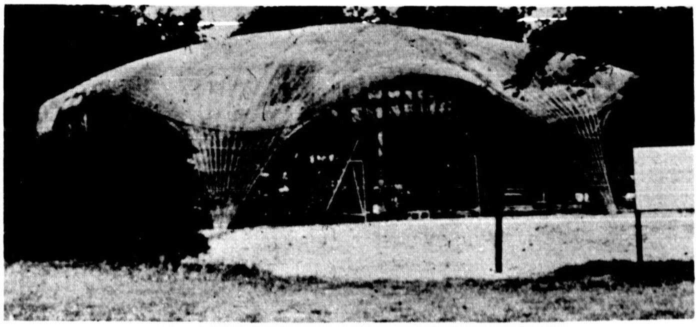


Figure 20. Final stage of construction — completed six-point parabolic shell.

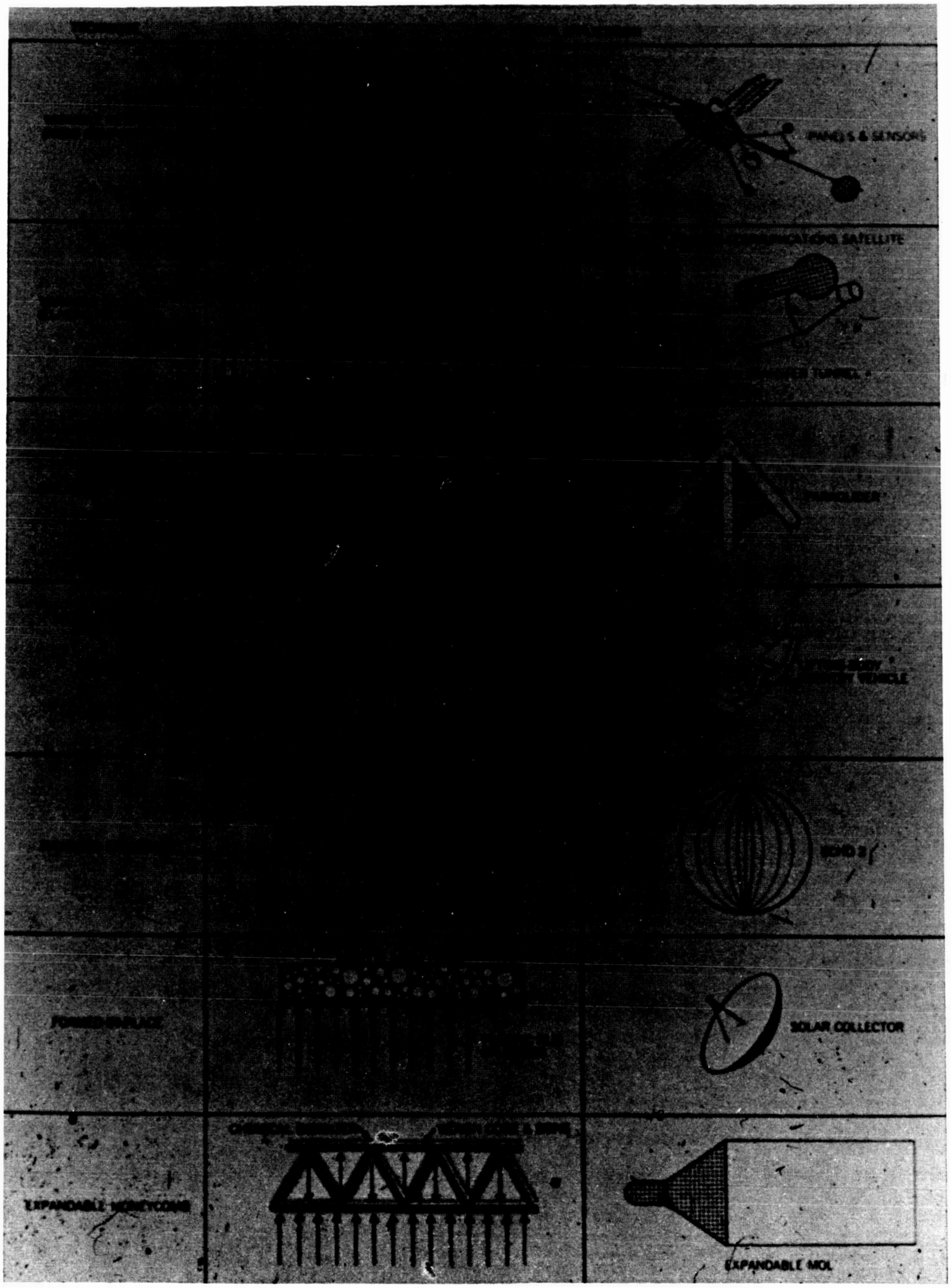


Figure 21. Expandable structures deployment technique and applications (courtesy of Space/Aeronautics).

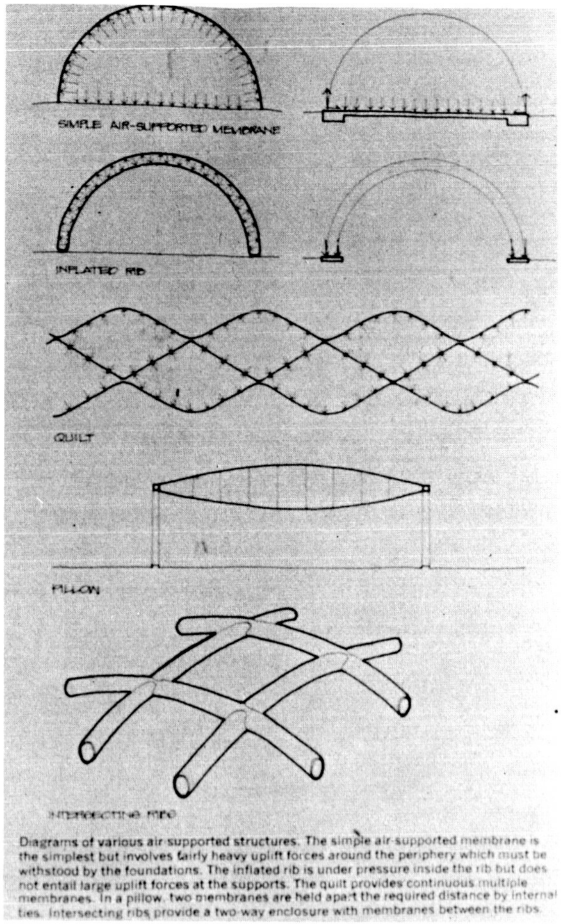


Figure 22. Diagrams of various air-supported structures (courtesy of Progressive Architecture).

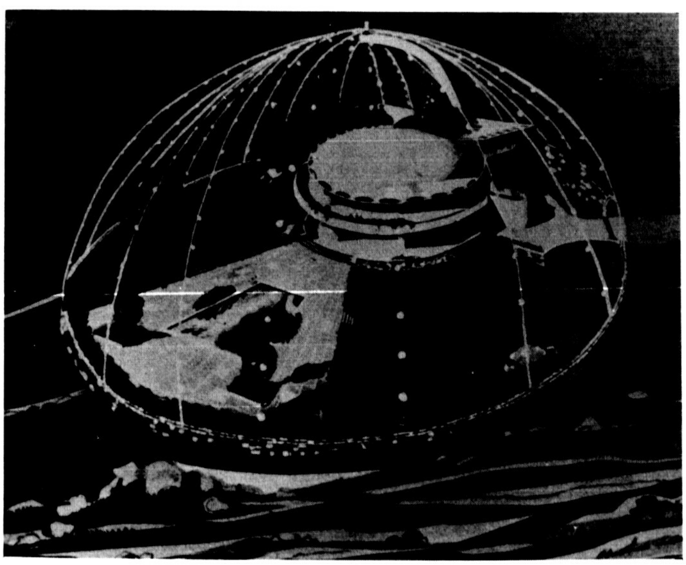


Figure 23. An oasis for living (courtesy of Machine Design).

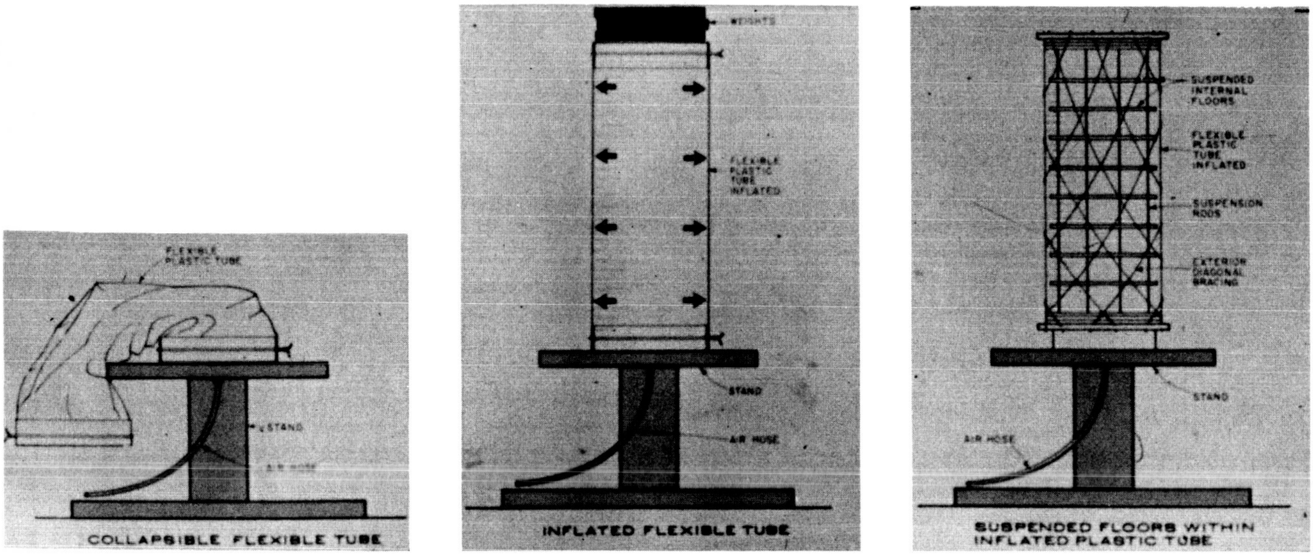


Figure 24. Pneumatic construction applied to multistory buildings (courtesy of Progressive Architecture).

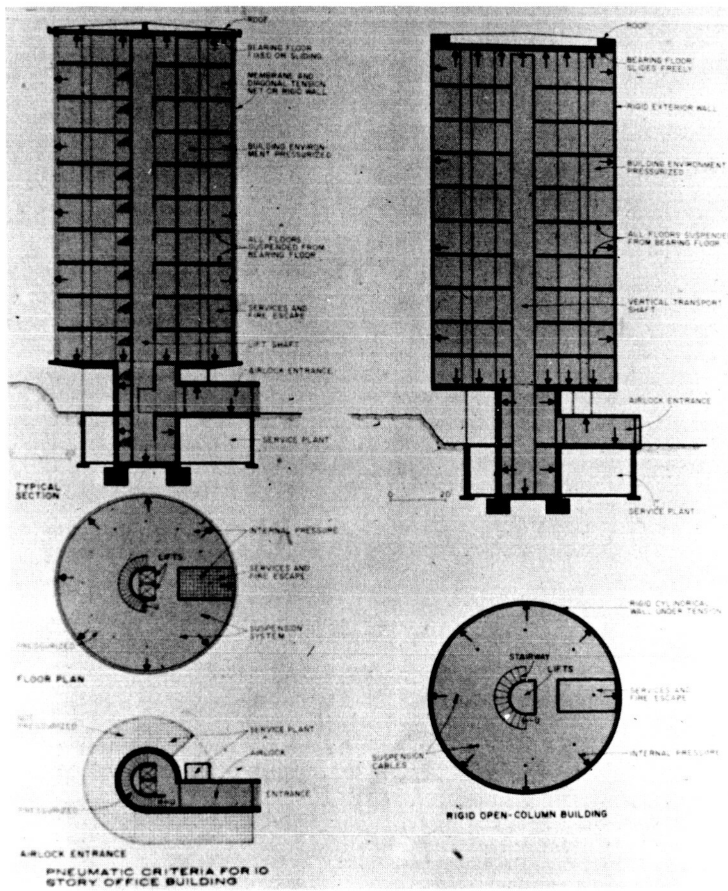


Figure 25. Office building designs (courtesy of Progressive Architecture).

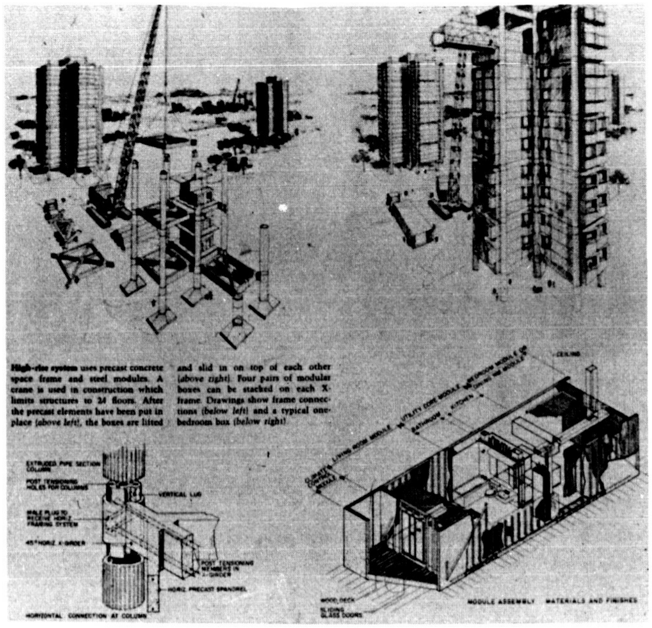


Figure 26. Modular high-rise system (courtesy of House and Home).

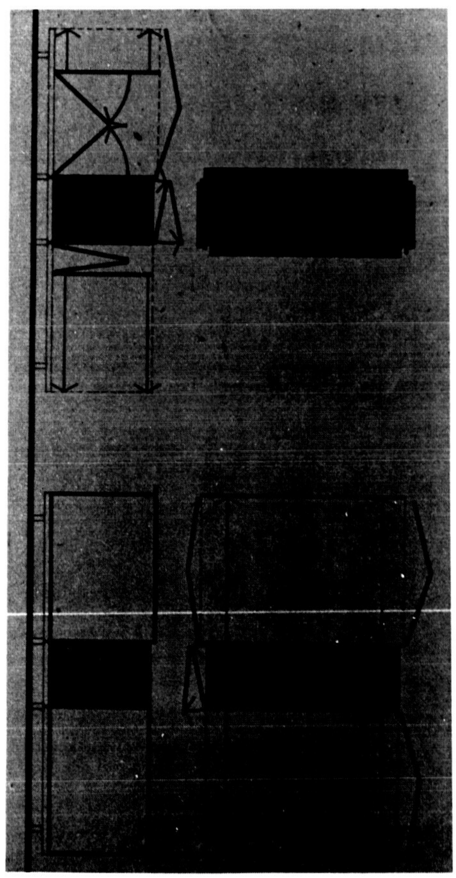
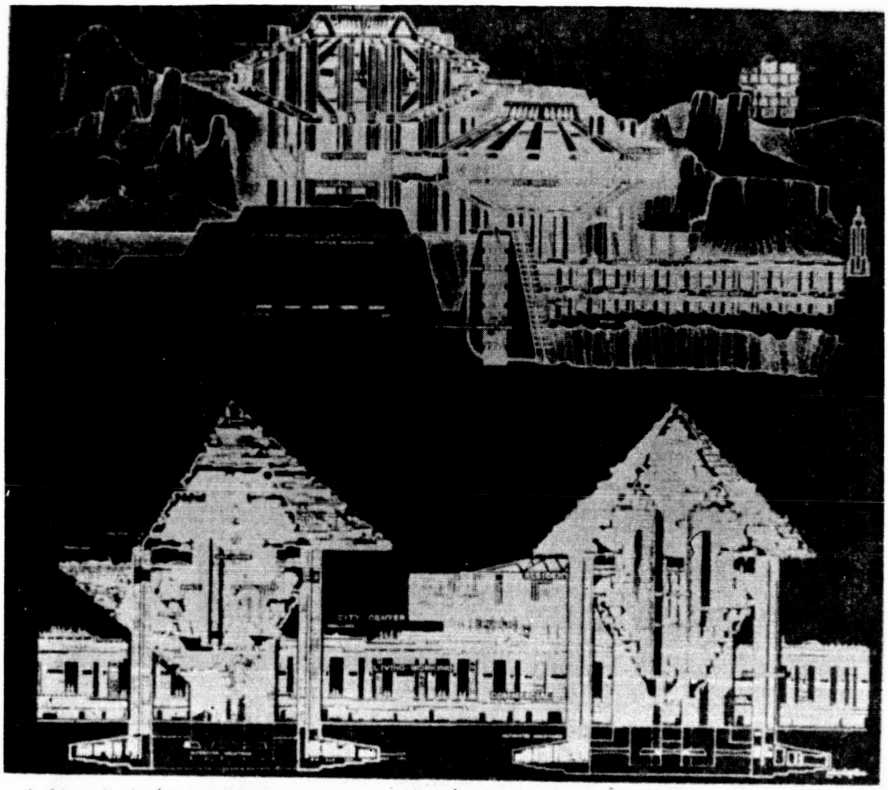


Figure 27. The Acron house [12].



Architect Paolo Soleri conceives future cities with more than a million people living in vast multi-level structures like these, dwarfing the Empire State Building, shown to scale right of top drawing.

Figure 28. Arcology [13].

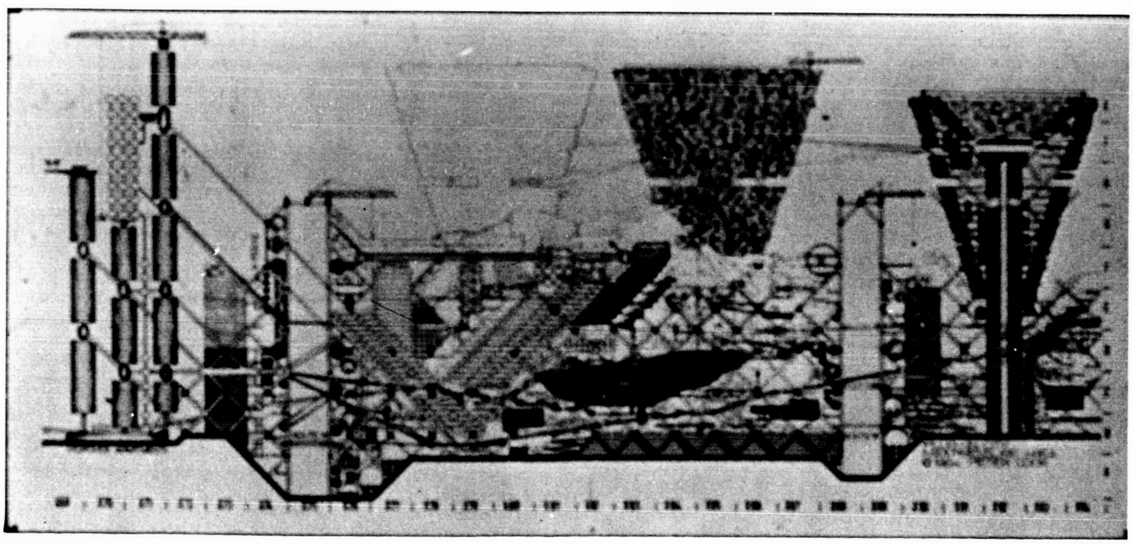


Figure 29. Plug-in city.

Figure 30. Super-roof structure.

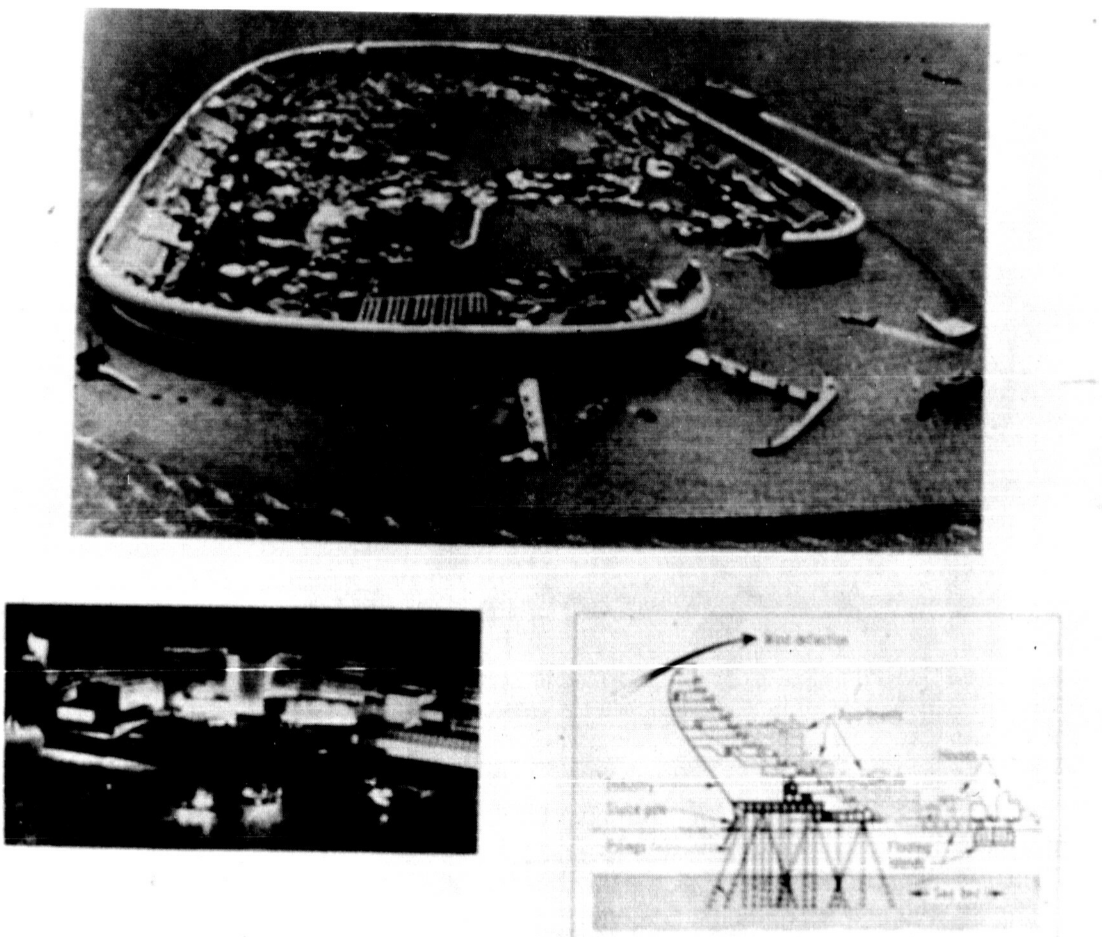


Figure 31. Sea city (courtesy of Machine Design).

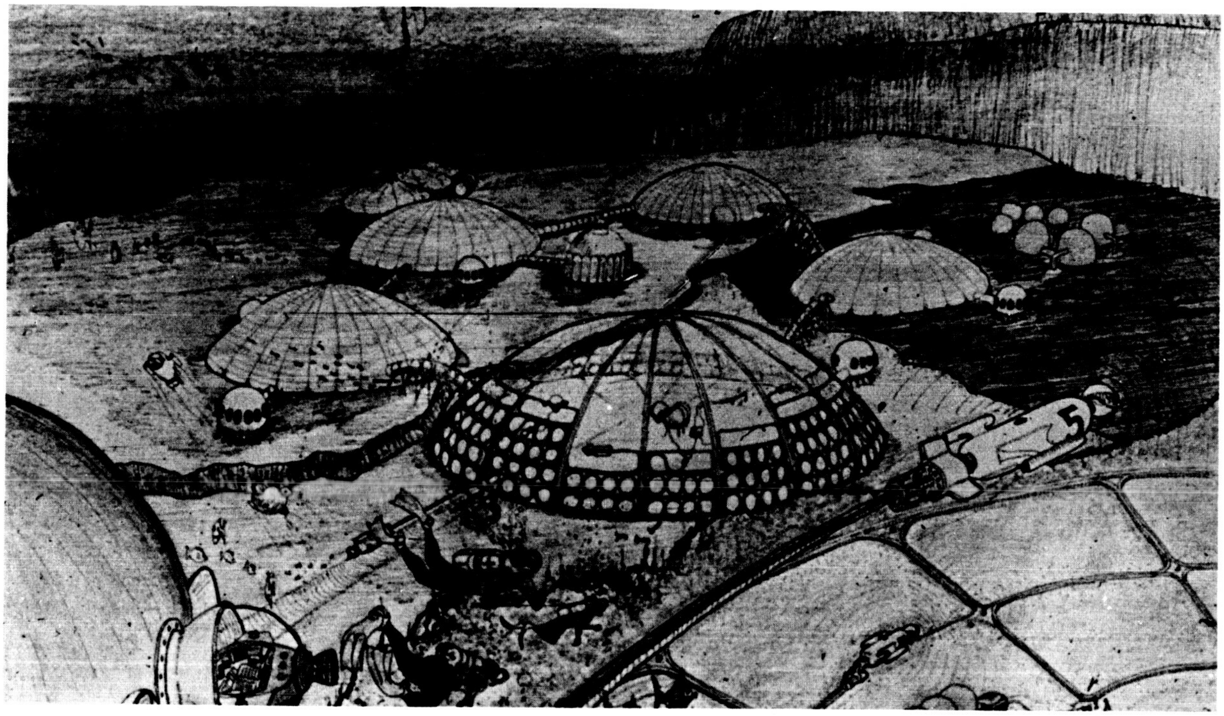


Figure 32. Undersea community (courtesy of Progressive Architecture).

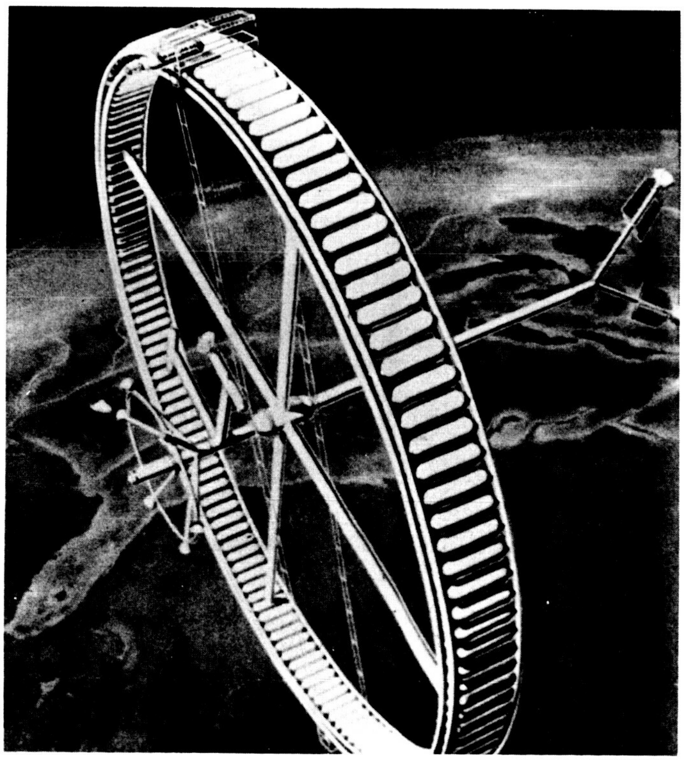


Figure 33. Space city.

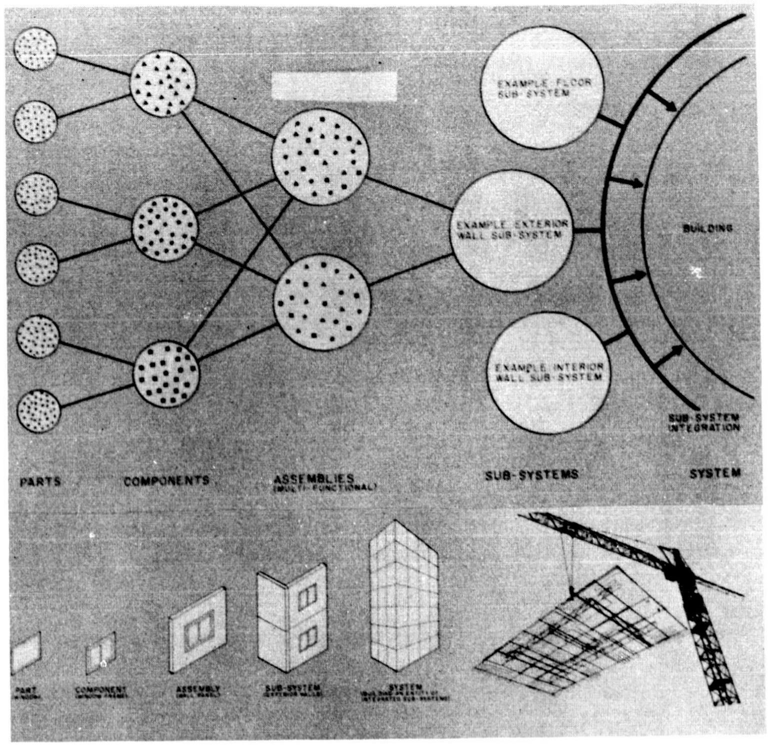


Figure 34. Systems definition (courtesy of Progressive Architecture).

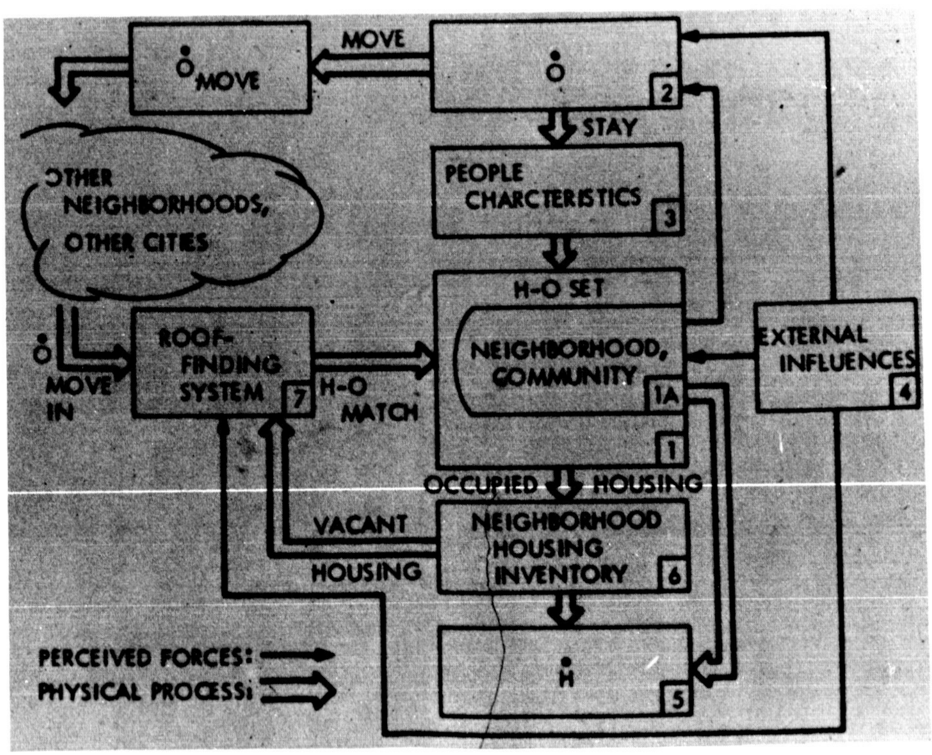


Figure 35. Major elements of the housing system [21].

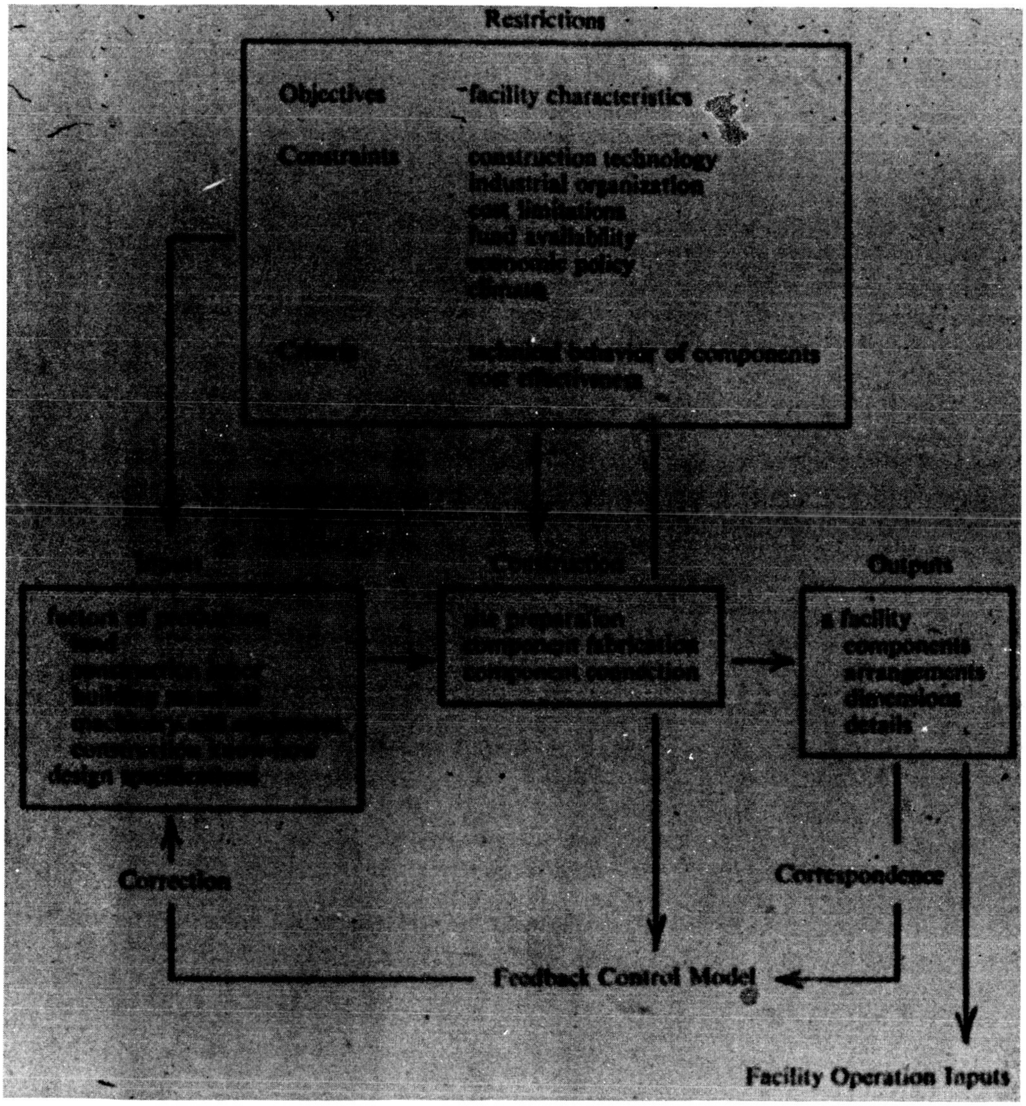


Figure 36. Structure of the construction subsystem [20].